Overview

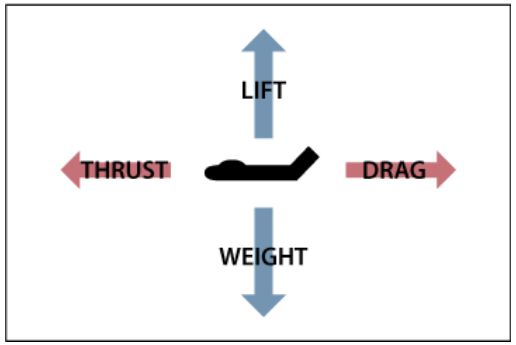
- What
  - The four forces of flight are in essence the fundamental principles that govern flight
  - They are what make the airplane fly
- Why
  - How a pilot performs in flight depends on the ability to plan and coordinate the use of power and flight controls to change the forces of lift, thrust, weight, and drag
  - The pilot must always control a balance between these forces
  - The better the understanding of the forces, the greater the pilot's skill

Content

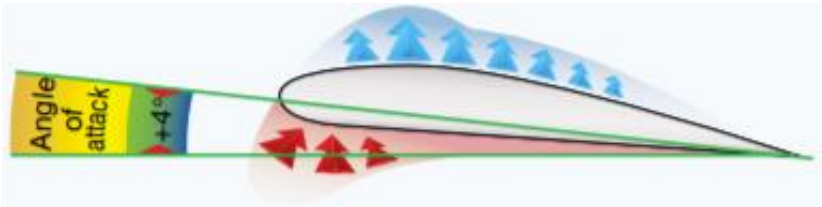
- Basics
- Lift
- Weight
- Thrust
- Drag
- Ground Effect
- Climbs
- Descents
- Turns
- Stalls

Basics

- Four Forces
  - Lift - Upward force created by the effect of airflow over / under the wing
  - Weight - Opposes lift, caused by the downward pull of gravity
  - Thrust - Forward force propelling the aircraft through the air
  - Drag - Opposes thrust, backward force limiting the speed of the airplane

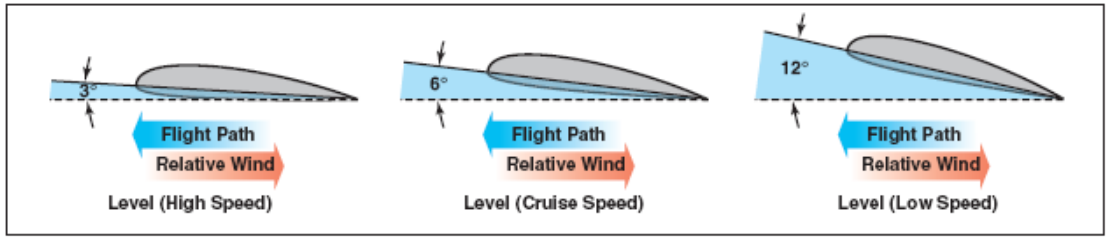


- Terminology
  - Chord Line: Imaginary straight line joining the leading and trailing edges of an airfoil
  - Relative Wind: Direction of movement of the wind relative to the aircraft's flight path
  - Angle of Attack: Angle between the chord line and the relative wind



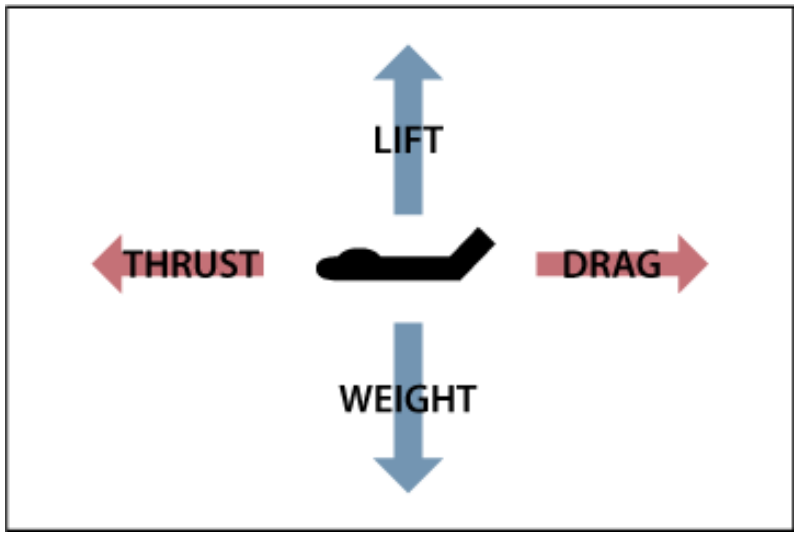
Lift

- Principles of Lift
  - Bernoulli's Principle: As the velocity of a fluid (air) increases, its pressure decreases
    - Curvature of the upper portion of the wing
  - Newton's 3rd Law: Every action has an equal and opposite reaction
    - Downwash / Air striking the lower surface of the wing
- Pilot Control of Lift
  - Lift = $\frac{1}{2}pC_LV^2S$
  - Pilot can control:
    - Angle of Attack (C_L) – Changing pitch changes AOA and therefore lift
    - Airspeed (V^2) – Lift is proportional to the square of airspeed
    - Surface Area (S) – Flaps and slats can increase surface area, otherwise S is constant during cruise



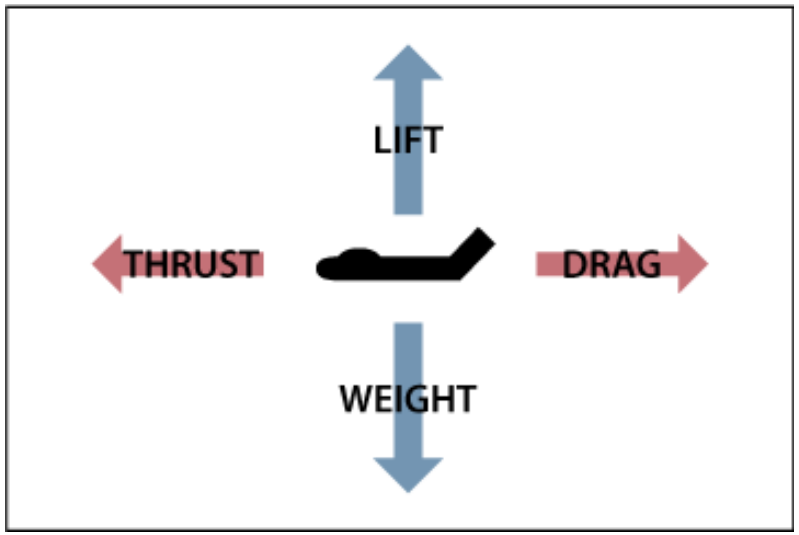
Weight

- Force of gravity acts vertically through the CG of the plane toward the center of the earth
  - Pulls the airplane down
- When lift equals weight, the plane is in equilibrium and doesn't gain or lose altitude
  - If weight is greater than lift, the airplane descends
  - If lift is greater than weight, the airplane climbs



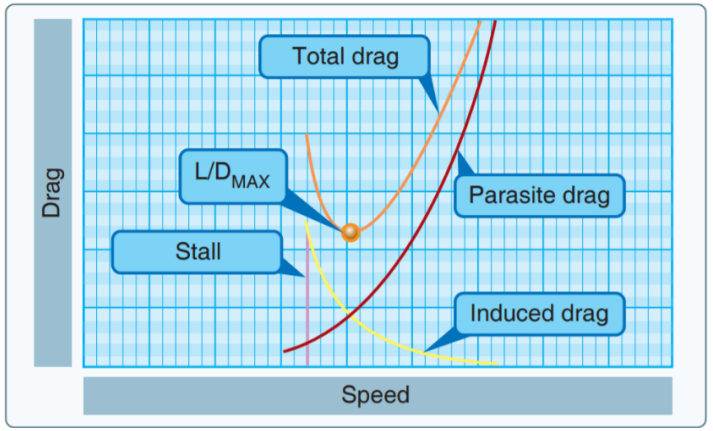
Thrust

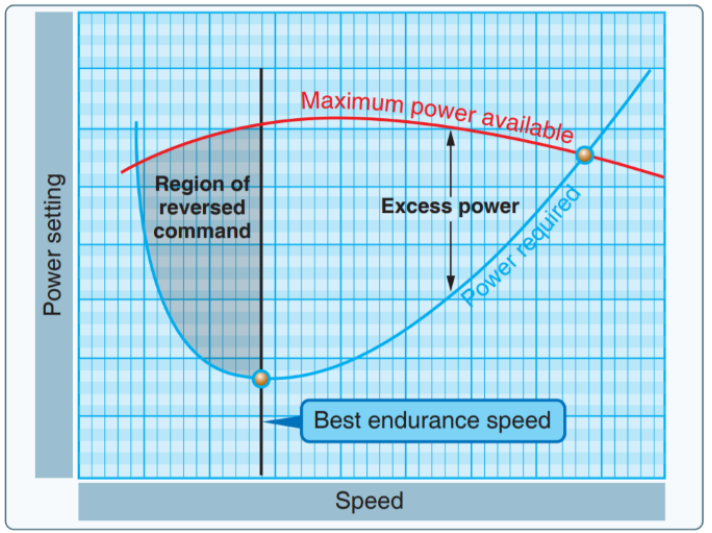
- Forward force which opposes drag
  - Force = Mass x Acceleration
- Airplane will continue to accelerate until thrust is equal to drag
  - If thrust is greater than drag, the airplane accelerates until thrust and drag are equal
  - If thrust is less than drag, the airplane decelerates until thrust and drag are equal



Drag

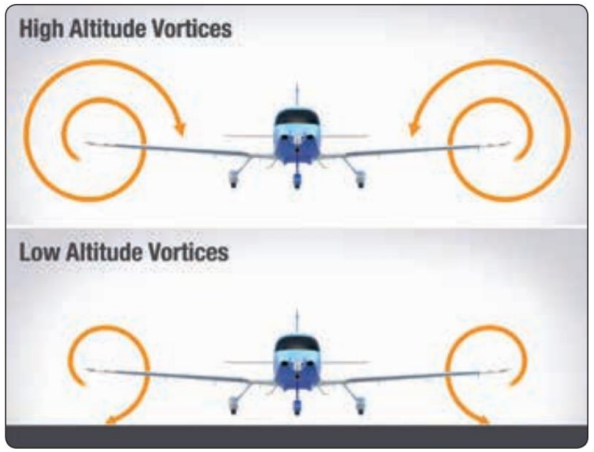
- Rearward force opposing thrust
- Types of Drag
  - Parasite Drag – Aircraft surfaces interfering with the smooth airflow over the plane
    - Form – Size and shape of the aircraft
    - Interference – Varied currents of air meeting / interacting
    - Skin Friction – Roughness of the airplane's surface
  - Induced Drag – Byproduct of lift
    - Caused by creation of wingtip vortices
- Total Drag: Parasitic Drag + Induced Drag
  - Region of Normal Command
    - As airspeed decreases, total drag decreases to a point (L/D Max)
  - Region of Reversed Command
    - Slower speeds require higher power settings

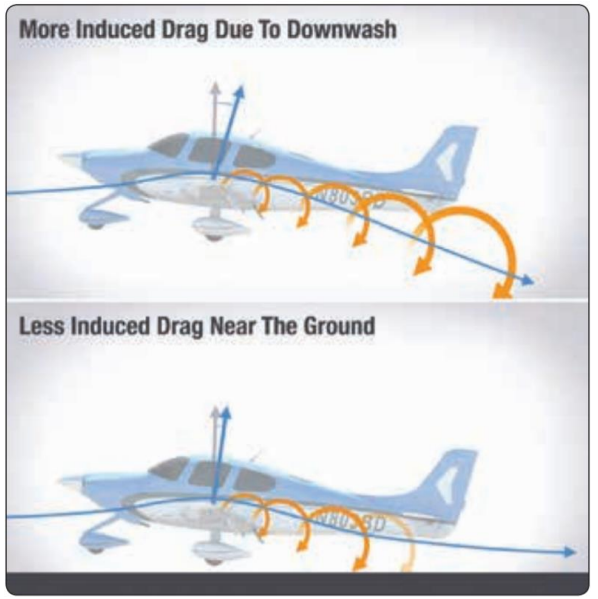




Ground Effect

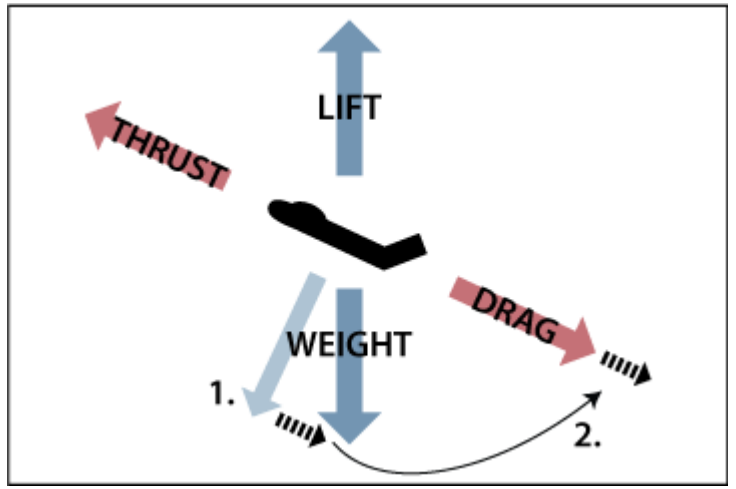
- Reduces induced drag
  - Vertical component of the airflow around the wing is restricted by the ground
- Effects on Flight
  - Takeoff: Capable of lifting off at a lower-than-normal speed
    - Drag increases when out of ground effect
  - Landing: Airplane seems to float in ground effect





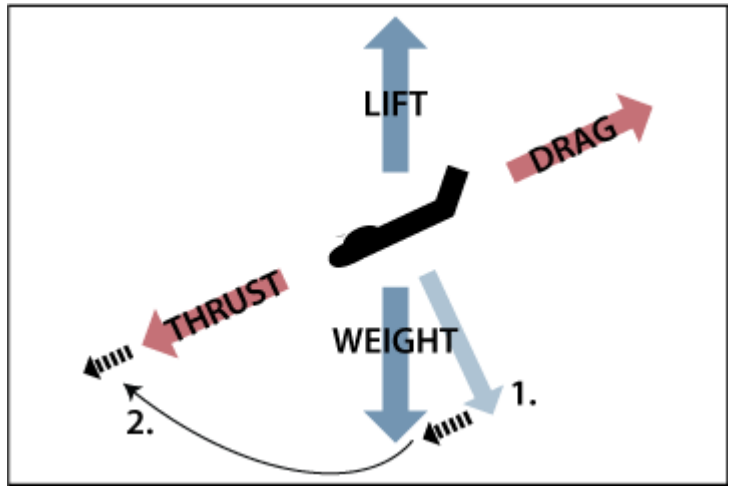
Climbs

- In a steady climb, lift is the same as in level flight at the same airspeed
  - Raising the airplane's nose increase AOA and momentarily increases lift
  - Once the climb is established, AOA and lift return to level flight values
- Airspeed in a Climb
  - With no change in power, airspeed will decrease in a climb
  - When inclined upward, a component of weight acts rearward and has the same effect as drag
    - The steeper the climb, the greater the effect
  - Additional power is required to maintain airspeed



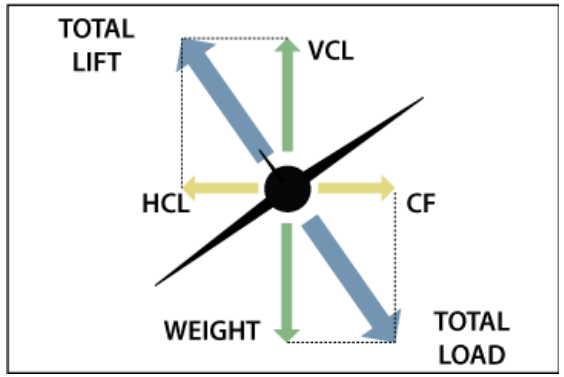
Descents

- Lowering the nose reduces AOA and lift momentarily
  - Lift is momentarily less than weight, changing the flight path
  - Once stabilized in the descent, AOA and lift return to level flight values
- With no change in power, airspeed will increase in a descent
  - A component of weight acts forward and has the same effect as thrust
    - The steeper the descent, the greater the effect
  - Power must be reduced to maintain airspeed

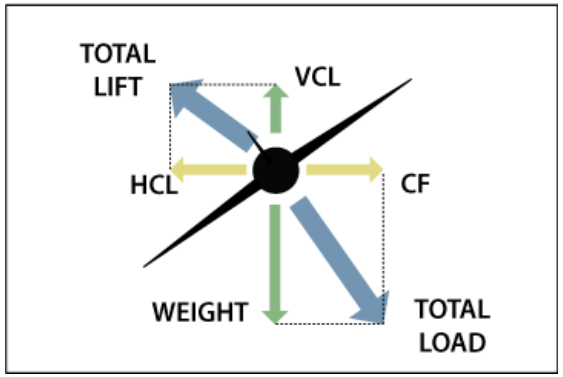


Turns

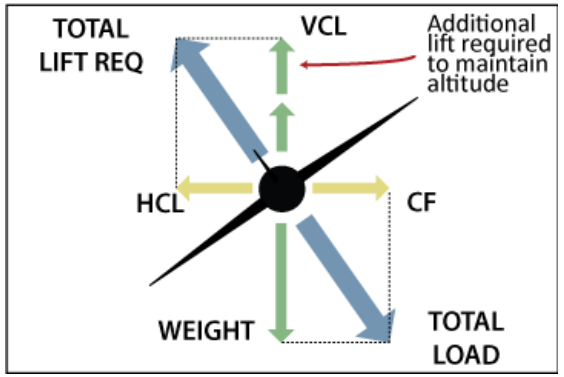
- Lift is divided into a Horizontal and Vertical component
  - Vertical – Acts vertically, opposite weight
  - Horizontal – Makes the plane turn (centripetal force)
- AOA in a Turn
  - Vertical lift is reduced while weight remains the same
  - AOA must be increased so the vertical component of lift equals weight
  - Increased AOA increases drag. Power is required to maintain speed



HORIZONTAL / VERTICAL COMPONENTS



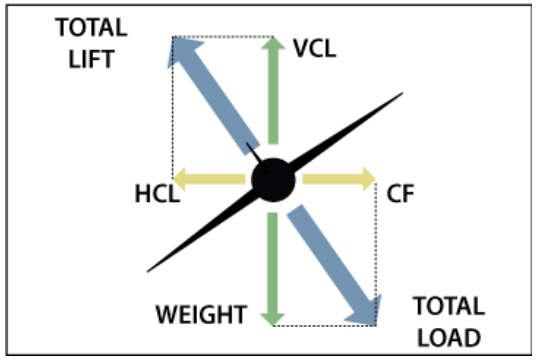
LEFT BANK, NO BACK PRESSURE



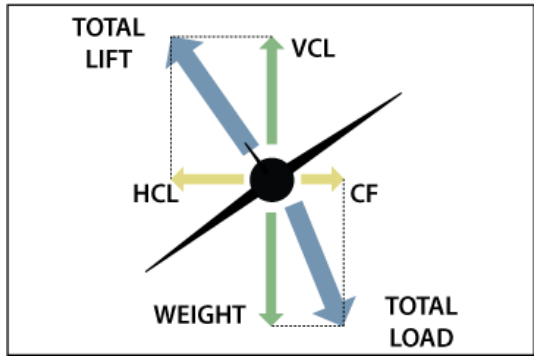
LEFT BANK + BACK PRESSURE

Turns

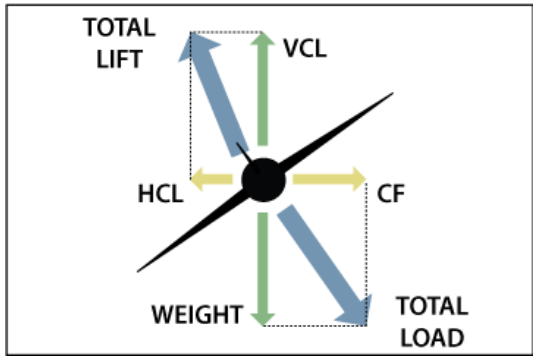
- Turn Rate and Radius
  - Rate of Turn – Varies with horizontal component of lift (bank angle)
  - Turn Radius – Varies with airspeed and bank angle
- Coordination
  - Coordinated Turn: Horizontal component of lift = Centrifugal force
  - Slipping Turn: Rate of turn is too slow for the bank angle
    - Horizontal component of lift is greater than centrifugal force
  - Skidding Turn: Rate of turn is too great for the bank angle
    - Centrifugal force is greater than the horizontal component of lift



COORDINATED TURN



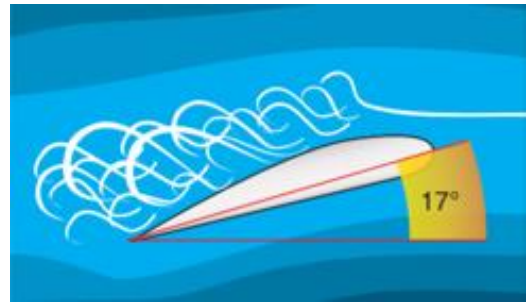
SLIPPING TURN

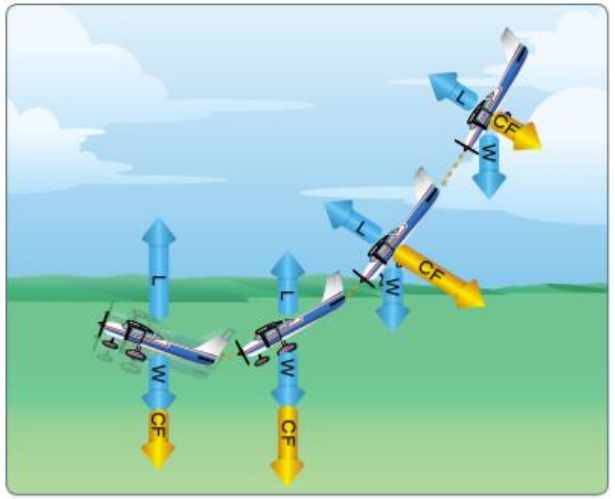


SKIDDING TURN

Stalls

- Direct cause of all stalls is an excessive angle of attack
  - Stall speed varies
  - Stall AOA is always the same (generally, 16-20 degrees)
- Stalls can occur in any phase of flight
  - Low Speed
    - As airspeed decreases, AOA must be increased to maintain altitude
  - High Speed
    - High speed dive with a sudden increase in back pressure
    - The plane cannot immediately change its flight path, AOA increases rapidly
  - Turning
    - Stall speeds are higher in a level turn than in straight-and-level flight
    - Wing must produce additional lift to counter the load imposed in a turn





Questions?